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EDITORIAL NOTES

The Precast Concrete Industry.

ONE of the outstanding developments in the concrete industry during the post-war years is the advance made in precast construction. Precasting concrete elements is as old as the industry itself and, as currently understood, dates from the middle of the nineteenth century. An interesting form of such construction applied to marine work fifty years ago was described in this journal last month. A national precast concrete organisation was established in Denmark fifty-two years ago. The editorial comments in this journal of that period were in general against structural precast concrete, such an application being considered to be opposed to a primary characteristic of reinforced concrete, that is the monolithic nature of structures built of this material. The difficulty of making satisfactory joints was emphasised, but this obstacle has in general been successfully overcome. Since those early days, however, the economy of precast construction for a wide range of structures, especially in respect of the saving in shuttering, and the advantage gained from casting under factory conditions, are recognised more keenly by engineers and contractors, so that today precast construction constitutes a not inappreciable fraction of concrete construction. It is not easy to determine accurately what this fraction may be but in the twenty or more countries which are members of the Bureau International du Béton Manufacturé, the precast industry represents upwards of 3 per cent. of the building industry, involving an annual turnover of about £350,000,000 and employing about 150,000 men. In some countries precasting is more extensive than in others. In Sweden, where the precast industry has increased tenfold in the past thirty years, a fifth of all the cement made in that country is used for precast products and construction.

The products industry is well established and, until recent years, represented the major activity in precasting, but the precasting of structural members has advanced to such a degree, aided in no small way by the convenience of precasting prestressed concrete members, that it is now approaching the products industry in importance. Referring again to statistics for Sweden, about 40 per cent. of the value of the industry's production consists of pipes, up to 25 per cent. blocks and light-weight structural units, and about the same proportion of structural and pre-stressed members. The extent of the development of precast construction throughout the world is one of the principal impressions gained from the third International Congress of the Precast Concrete Industry held in Stockholm in

June last. In this respect Great Britain does not seem to lag behind other countries as in this country precast beams exceeding 100 ft. in length or upwards of 100 tons in weight and framed multiple-story buildings with wall panels 17 ft. by 15 ft. in one piece have been precast. There may, however, be a greater volume of precast work abroad resulting from a greater degree of standardisation of structural units, which can lead to economical manufacture and speedy erection especially in the case of multiple-story blocks of flats. In the U.S.A. and Sweden, and probably elsewhere, the prefabrication of entire rooms, such as kitchens and bathrooms complete with plumbing and other fixtures, is no longer a novelty. In one instance in Sweden, although admittedly under idealised conditions, a house of seven rooms was erected in eleven hours by utilising standard parts. On a more practical basis, a building containing forty residential flats has been built in France in fifty-two days by utilising precast construction in the superstructure, which was erected in nine days. The adoption of precast construction, with or without standardisation, is only justified generally on the grounds of economy, which in many countries means reduction in the labour required to make the parts and erect the structure, since the materials which constitute concrete, and generally the reinforcement, are indigenous. An investigation of nineteen blocks of flats was made in Sweden. Expressing the labour requirements in terms of man-hours per cubic yard of building, it was estimated that for buildings of three and four stories, traditional methods of construction required fourteen to eighteen man-hours but the time could be reduced to less than eleven man-hours, three of which were occupied in factories, if prefabrication was used; if all the work was carried out on the site, the time exceeded that of traditional methods. For buildings of nine to thirteen stories, traditional construction required on the average about seventeen man-hours, but prefabricated construction required only thirteen man-hours of which a little more than two were occupied in factories. The speedy erection of precast frames for single-story buildings is now commonplace; a recent example in Great Britain is that of a structure 225 ft. long and 50 ft. wide, the frames of which were erected in four days.

A commendable feature of the Congress, apart from the fact that it is a triennial, and not an annual, event, was the series of informal discussions of specific subjects which produced practical data and ideas to supplement the information in the more formal papers and reports. Although many of the subjects are of interest mainly to the precast industry, some will appeal to those concerned with other aspects of concrete engineering.

Whether standardisation is a good thing or not was one of the subjects discussed informally, and it was held that architects, in Great Britain at least, would not take kindly to standard wall panels, floor beams, and other building components if it meant that freedom of design and planning would be restricted. Bridges constructed with standard precast girders cannot be said to compare favourably in appearance with those of more varied design of cast-insitu construction. Not long ago the objectionable feature of reinforced concrete construction was the drab discolouration of the surfaces of buildings otherwise of architectural pretensions. Today a variety of successful and economical methods of surface treatment, mainly attributable to adopting factory-made precast panels, have made this objection less valid, but may have replaced it by the evil of uniformity as seen in some of the new box-like buildings even where attempts are made to vary the arrangement of the precast panels to provide some sort of pattern.

An Analysis of Slabs Supported along all Edges.

By E. H. MANSFIELD, Sc.D.

THE method of determining the loads causing the collapse of steel frames[1] can be applied to concrete slabs although additional information is required because of the presence of the two principal bending moments. The analysis in the following is based on a method developed by the writer.[2]

Under the action of the two moments, yielding of a " rigid-plastic " slab occurs when the principal moments satisfy the " yield criterion ". The term " rigid-plastic " describes a slab such that when the moments on the slab are less than the yield-moments the deflections may be neglected in comparison with those that occur when the yield-moment is reached, that is, the slab is regarded as rigid until collapse occurs. In the following the case is considered in which the reinforcement is not symmetrically disposed about the mid-plane

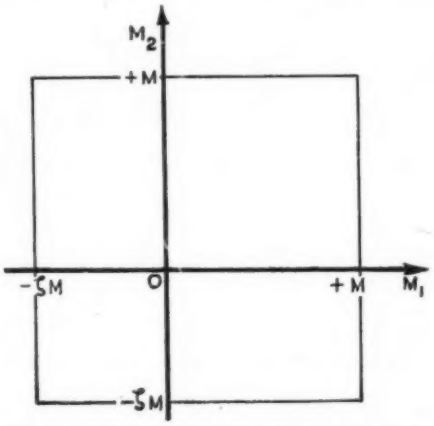


Fig. 1.—Eccentric Square Yield Diagram.

of the slab, so that the positive and negative yield-moments differ. For such slabs an " eccentrically-placed square yield criterion " as described by K. W. Johansen is adopted in this article and is the diagram in *Fig.* 1, in which the bending-moments M_1 and M_2 in two directions are shown on the ordinate and abscissa respectively.

Yielding occurs when either of the principal moments attains the value of $+M$ or $-\zeta M$. Moments are considered to be negative when they cause tension at the top of a slab as at a support, and positive when there is tension at the bottom of a slab as at the middle of a freely-supported span. The direction of the principal rate of curvature coincides with that of this principal moment, the other principal rate of curvature being zero. Arbitrary forms for the distribution of plastic hinges are prescribed and the least load to cause collapse with respect to these distributions is determined. It is assumed that the slab

is not so thin that the load would be resisted by direct or membrane forces before the formation of plastic hinges.

Collapse of Slabs Subjected to Central Concentrated Loads.

REGULAR POLYGONAL SLABS FREELY SUPPORTED AT THE EDGES.—If the number of sides n is sufficiently large the hinges formed by positive bending moments will be as shown in *Fig.* 2. If the slab under the load P deflects an amount Δ the hinges rotate through an angle $(2\Delta/R)\tan(\pi/n)$ and the total work done in the hinges is accordingly $2\Delta nM\tan(\pi/n)$. Equating this work to the work done by the applied load, $P\Delta$, gives, by the principle of virtual work, $P/M = 2n\tan(\pi/n)$.

CIRCULAR SLABS WITH FREELY-SUPPORTED EDGES.—This may be regarded as the limiting case of the regular polygon as n tends to infinity. The mode of collapse will be a " hinge field " rather than a system of discrete hinges. Most modes of collapse are composed of hinge fields in addition to hinge lines.

The load causing collapse is given by $P/M = 2\pi$.

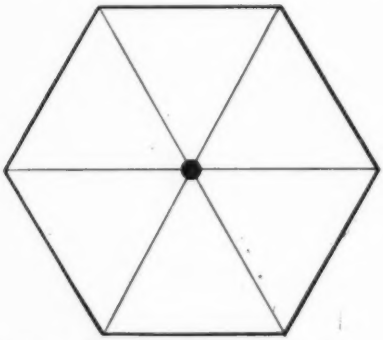


Fig. 2.—Regular Polygonal Slab.

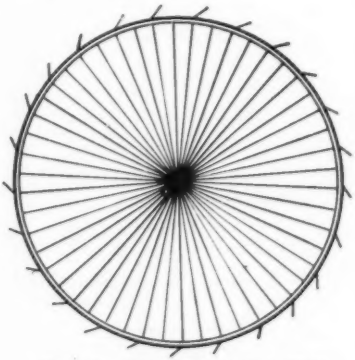


Fig. 3.—Fixed Circular Slab.

CIRCULAR SLABS WITH FIXED EDGES.—The mode of collapse is as shown in *Fig.* 3. Under a small displacement it is found that the work done in the circumferential hinge which is formed by negative bending moments is ζ times that in the hinge field, so that the load causing collapse is given by $P/M = 2\pi(1+\zeta)$.

An alternative mode of collapse with the same load occurs when the slab in the annulus between the circumferential hinge and the boundary is still elastic though developing the plastic moment, and therefore simulates the conditions of fixity at the boundary. By altering the shape of the boundary of the elastic annulus neither the load causing collapse nor the " natural mode of collapse " (*Fig.* 4) is altered and the load causing collapse is given by the same formula.

SQUARE SLABS WITH FREELY-SUPPORTED EDGES.—In the vicinity of the corners of the square the slab is relatively stiffly secured against vertical movement at the intersecting boundaries. It is therefore reasonable to suppose that the mode of failure may be as in *Fig.* 5, which incorporates sectors of the " natural mode of collapse " considered previously.

With the notation of *Fig.* 5 the load causing collapse is given by

$$P/M = 8 \cot \lambda + (1 + \zeta)(8\lambda - 2\pi), \quad . \quad . \quad . \quad (1)$$

which is least when $\sin \lambda = (1 + \zeta)^{-\frac{1}{2}}$ and is given by

$$P/M = 8\sqrt{\zeta} + (1 + \zeta)[8 \sin^{-1} \{(1 + \zeta)^{-\frac{1}{2}}\} - 2\pi]. \quad . \quad . \quad (2)$$

From geometrical considerations the angle λ cannot be less than $\frac{1}{4}\pi$, therefore equation (2) is not valid when ζ is greater than unity, in which case $\frac{P}{M} = 8$. The variation of $\frac{P}{M}$ with ζ is shown in *Fig.* 10.

These results may be used to determine the optimum distribution of reinforcement above the mid-plane, characterised by the ratio ζ. If the slab were

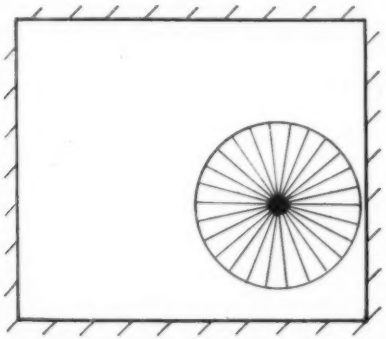


Fig. 4.—Fixed Arbitrary Slab.

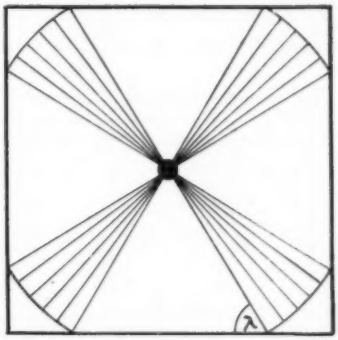


Fig. 5.—Freely-supported Square Slab.

equally reinforced above and below its mid-plane the value of ζ would be unity and from equation (2) the load causing collapse would be given by $\frac{P}{M} = 8$. However, the same strength may be attained with a reduced value of ζ for most of the slab. Thus, substituting $\frac{P}{M} = 8$ in equation (1) gives

$$\cot \lambda + (1 + \zeta)(\lambda - \tfrac{1}{4}\pi) - 1 = 0, \quad . \quad . \quad . \quad (3)$$

from which the value of ζ appropriate to a given value of λ may be determined. Lines joining equal values of ζ at various points on the slab are shown in *Fig.* 6, where it will be seen that throughout the area of the inscribed circle of the square the value of ζ is given by equation (3), with $\lambda = \frac{1}{4}\pi$, that is $\zeta = (4/\pi) - 1 = 0{\cdot}273$.

A slab with such a distribution of reinforcement as shown in *Fig.* 6 would not have a unique mode of collapse but would fail in any one (or combination) of the modes typified in *Fig.* 5. An increase of the value of ζ for the slab would not enable a greater load to be supported.

Collapse of Slabs Subjected to Eccentrically-applied Concentrated Loads.

The cases considered so far are characterised by the formation of hinge fields which are sectors of a circular natural mode of collapse. When a load is applied

eccentrically there is a possibility of the occurrence of hinge fields of a different shape.

Consider the radial hinge field shown in *Fig.* 7. The shape of the curved peripheral hinge is arbitrary, but by using variational methods a differential equation governing its behaviour can be found as follows. Impart a downward displacement Δ at the point O and apply the condition that the work done in the peripheral hinge plus that in the hinge field is a minimum. It is preferable to work in polar co-ordinates. It has been shown by A. R. Rzhanitsyn[3] that the total work done is given by

$$W = M\Delta \int_{\theta_1}^{\theta_2} \left\{ 1 + \zeta + \frac{(2+\zeta)}{r^2}\left(\frac{dr}{d\theta}\right)^2 - \frac{1}{r}\frac{d^2r}{d\theta^2} \right\} d\theta. \quad . \quad . \quad . \quad (4)$$

The relation between r and θ is to be determined from the condition that W is a minimum. It follows from the calculus of variations that r must satisfy the differential equation $\left(\frac{dr}{d\theta}\right)^2 - r\frac{d^2r}{d\theta^2} = 0$; integrating gives $r = r_0 e^{\theta \tan \phi}$, where r_0 and ϕ are arbitrary constants to be determined from the conditions at the

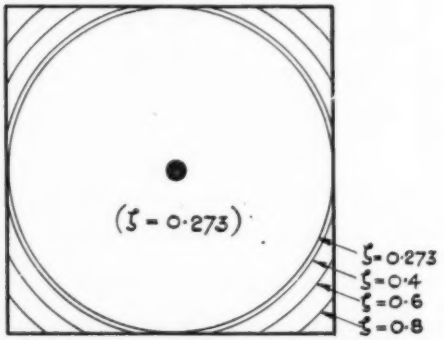


Fig. 6.—Square Slab with Optimum Strength.

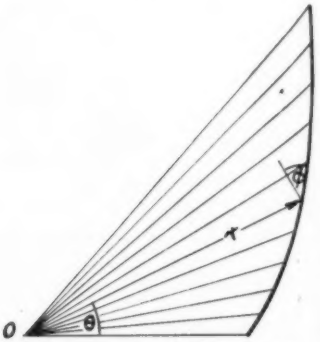


Fig. 7.—Radial Hinge Field.

peripheral hinge. This expression represents an equiangular spiral in which ϕ is the angle the spiral makes with a normal to the radius as shown in *Fig.* 7. The circular mode of collapse previously considered corresponds to the case when ϕ is zero.

Substituting the expression for r in equation (4) gives

$$W = M\Delta(1 + \zeta)(\theta_2 - \theta_1) \sec^2 \phi. \quad . \quad . \quad . \quad . \quad (5$$

The shape of the peripheral hinge can now be determined and hence the concentrated load, at any part of the slab, which would cause failure.

THE MODE OF COLLAPSE BETWEEN TWO INTERSECTING FREELY-SUPPORTED EDGES. Consider the mode of collapse in the region between two intersecting freely-supported edges as shown in *Fig.* 8. The edges intersect at an angle β and the load is applied at distances l and kl from the edges. Using the notation shown in *Fig.* 8 the equations relating r_0 and ϕ to λ_1 and λ_2 are

$$r_0 = l \operatorname{cosec} \lambda_1, \quad \text{and} \quad \tan \phi = \frac{1}{(\lambda_1 + \lambda_2 - \beta)} ln\left(\frac{k \sin \lambda_1}{\sin \lambda_2}\right) \quad . \quad (6$$

Now, since $\bar{W} = W + W_{OQ} + W_{OR}$,

$$\bar{W} = M\Delta\left[\cot\lambda_1 + \cot\lambda_2 + (1+\zeta)(\lambda_1+\lambda_2-\beta) + \left(\frac{1+\zeta}{\lambda_1+\lambda_2-\beta}\right)\left\{ln\left(\frac{k\sin\lambda_1}{\sin\lambda_2}\right)\right\}^2\right], \quad . \quad (6a)$$

from which the following simple relations between λ_1, λ_2 and ϕ can be derived by minimising $\bar{W}$ with respect to λ_1 and λ_2.

$$-\tan\phi = \frac{\sqrt{\frac{\zeta}{1+\zeta}} - \cos\lambda_1}{\sin\lambda_1}; \quad +\tan\phi = \frac{\sqrt{\frac{\zeta}{1+\zeta}} - \cos\lambda_2}{\sin\lambda_2}. \quad . \quad (6b)$$

GENERAL CONDITIONS AT BOUNDARIES.—If the ratio ζ in a continuous slab changes from one side of a support to the other, a hinge will exist in the weaker slab at the support and the conditions at the support for the stronger slab will

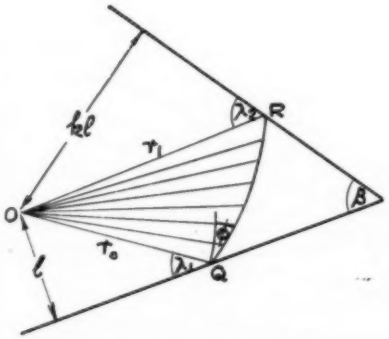


Fig. 8.—Mode of Collapse between Intersecting Freely-supported Edges.

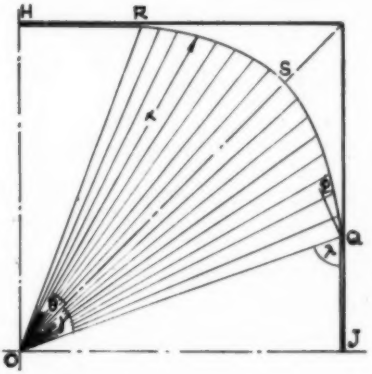


Fig. 9.—Quadrant of Uniformly-loaded Square Slab.

be intermediate between those of freely-supported and fixed edges. If such an edge has a fully plastic moment of μM, where $0 < \mu < \zeta$, the following relations exist between λ_1, λ_2 and ϕ, μ_1, μ_2:

$$\left.\begin{aligned} -\tan\phi &= \frac{\sqrt{\{(\zeta-\mu_1)/(1+\zeta)\}} - \cos\lambda_1}{\sin\lambda_1} \\ +\tan\phi &= \frac{\sqrt{\{(\zeta-\mu_2)/(1+\zeta)\}} - \cos\lambda_2}{\sin\lambda_2} \end{aligned}\right\} \quad . \quad . \quad . \quad (7)$$

Equations (7) are still valid if the boundary is convex, but if the boundary is concave it is necessary to replace $(\zeta-\mu)/(1+\zeta)$ by $\frac{\zeta-\mu}{1+\zeta} - \left|\frac{d\psi}{d\theta}\right|$. In terms of the radius of curvature r_c of the boundary $\frac{d\psi}{d\theta} = \frac{r}{r_c\sin\lambda}$.

As an example of the use of equation (7), consider a centrally-loaded square slab whose boundaries can develop negative yield-moments μM. Because of symmetry in the mode of collapse the angle ϕ is zero and the angle λ is therefore found from equations (7) to be given by $\cos\lambda = \left(\frac{\zeta-\mu}{1+\zeta}\right)^{\frac{1}{2}}$.

Referring to *Fig.* 5 the load causing collapse is given by

$$\frac{P}{M} = 8(1+\mu)\cot\lambda + (1+\zeta)(8\lambda - 2\pi).$$

Eliminating λ, $\frac{P}{M} = 8\sqrt{\{(\zeta-\mu)(1+\mu)\}} + (1+\zeta)\left[8\cos^{-1}\left(\frac{\zeta-\mu}{1+\zeta}\right)^{\frac{1}{2}} - 2\pi\right]$.

The variation of $\frac{P}{M}$ with ζ for various values of μ is shown in *Fig.* 10.

Collapse of a Square Slab under a Uniformly-distributed Load.

The analysis of the collapse of a square slab under a uniformly-distributed load is as follows. The boundary of the slab is assumed to be such that the

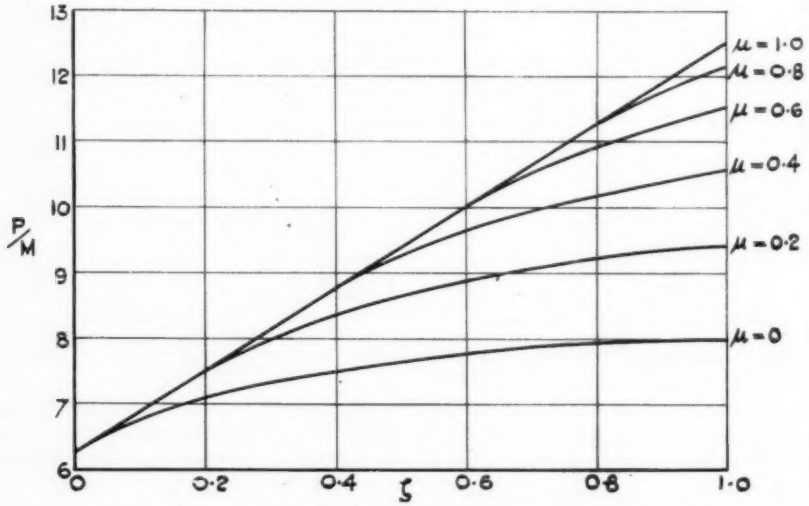


Fig. 10.—Collapse-load for Centrally-loaded Square Slab.

plastic moment there is $\mu M (0 \leqslant \mu \leqslant \zeta)$, and the general mode of collapse (*Fig.* 9) is symmetrical about a diagonal and is determined by the angle λ and the shape of the curved hinge QS. It can be shown[2] that

$$\alpha\tanh\left[\alpha\left(\lambda - \frac{\pi}{4}\right)\right] = \frac{\cos\lambda - \sqrt{\frac{\zeta-\mu}{1+\zeta}}}{\sin\lambda}, \quad \text{and} \quad \alpha = \left[\frac{4\left(\frac{\zeta-\mu}{1+\zeta}\right)^{\frac{1}{2}}\sin\lambda}{\sin 2\lambda - 2\lambda + \frac{\pi}{2}} - 1\right]^{\frac{1}{2}},$$

from which λ and α can be determined, and the load which would cause collapse is given by

$$\frac{pa^2}{6M(1+\zeta)} = \left[\frac{\alpha \sin \lambda}{\cosh\{\alpha(\lambda - \tfrac{1}{4}\pi)\}}\right]^2.$$

The variation of $\frac{pa^2}{M}$ with ζ for various values of μ are shown in *Fig.* 11.

Example.

A uniformly-reinforced long concrete strip, for which $\zeta = \frac{9}{16}$, is freely supported at the edges. Compare the magnitudes of the concentrated loads which will cause failure when, (a) the load is applied midway between the edges and (b) the load is twice as far from one edge as from the other and is on the minor axis of the slab.

(a) The mode of collapse may be derived from that between two intersecting freely-supported edges and is shown in *Fig.* 8 with β equal to zero and the edges

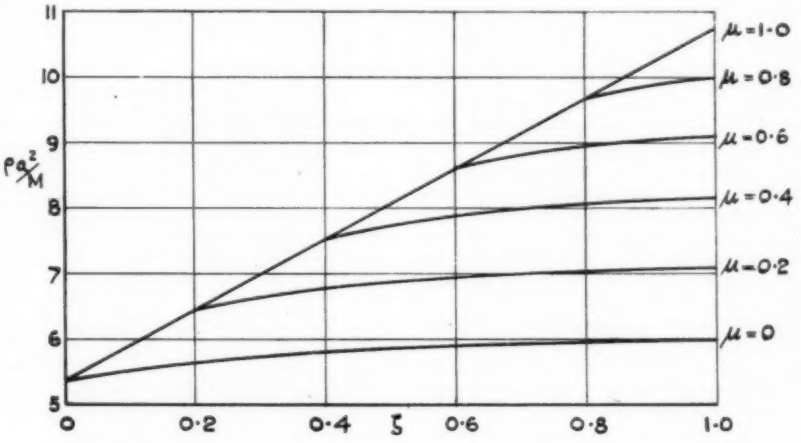


Fig. 11.—Collapse-load for Uniformly-loaded Square Slab.

parallel. From symmetry, the radial hinge fields will be circular ($\phi = 0$) and the angle λ will be given by equation (6a) such that $\cos \lambda = \sqrt{\{\zeta/(1+\zeta)\}} = 0{\cdot}6$.

The load causing collapse may now be determined from equation (6a), bearing in mind that two sets of hinges are formed, one on each side of the load. Then,

$$P = 4M\{\cot \lambda + (1+\zeta)\lambda\} = 4M\left(0{\cdot}75 + \frac{25}{16} \times 0{\cdot}927\right) = 8{\cdot}79M.$$

(b) In this case there are two possible modes of collapse to consider; either the peripheral hinge will form a continuous circular arc intersecting the nearer edge but missing the further edge, or two similar hinges will form, as in case (a), except that they will be equiangular spirals rather than circular arcs. The load causing collapse for the continuous circular arc may be obtained from equations

(6a) and (6b) and *Fig.* 8 if $\beta = -\pi$, $k = 1$, $\phi = 0$, so that $\cos\lambda = 0{\cdot}6$. From equation (6a)

$$P = M\left[2\cot\lambda + \frac{25}{16}(\pi + 2\lambda)\right] = 9{\cdot}31M.$$

The form of the equiangular spiral hinges may be obtained from equations (6) and (6b), with $\beta = 0$ and $k = 2$. Thus,

$$\tan\phi = \frac{1}{(\lambda_1 + \lambda_2)} ln\left(\frac{2\sin\lambda_1}{\sin\lambda_2}\right) = \frac{\cos\lambda_1 - 0{\cdot}6}{\sin\lambda_1} = \frac{0{\cdot}6 - \cos\lambda_2}{\sin\lambda_2}.$$

These equations may be solved to give $\lambda_1 = 0{\cdot}738$, $\lambda_2 = 1{\cdot}147$, $\phi = 0{\cdot}204$, whence, from equation (6a), $P = 9{\cdot}24M$. This value for P is less than that corresponding to the continuous-circular-arc mode of collapse and it is therefore the true value. The load causing collapse for case (b) is thus 5 per cent. greater than that for case (a).

REFERENCES.

1.—BAKER, J. F. "A Review of Recent Investigations into the Behaviour of Steel Frames in the Plastic Range." Journal of the Institution of Civil Engineers, No. 3, Vol. 31, 1949.

2.—MANSFIELD, E. H. "Studies in Collapse Analysis of Rigid-plastic Plates with a Square Yield Diagram." Proceedings of the Royal Society, A, Vol. 241 (1957).

3.—RZHANITSYN, A. R. Structural Analysis Taking Account of Plastic Properties. Moscow, 1954.

Research on Biological Shields.

IT is announced in the annual report for 1959, issued by the Building Research Station of the Department of Scientific and Industrial Research, that research is to be undertaken to investigate the effects of temperature, drying shrinkage, creep and radiation in connection with the massive concrete biological shields in the reactors being constructed at nuclear power stations in Great Britain. The investigation, which is being undertaken in collaboration with the United Kingdom Atomic Energy Authority (Industrial Group), will be in two parts, the first being laboratory studies of the properties of concrete, and the second being long-term observations on the biological shields at Calder Hall and Chapelcross. In the first reactor to become operational, that is at Calder Hall, observations show that little drying of the concrete has yet taken place and that the temperatures of the concrete are rather lower than expected. Instruments have also been installed in two of the nuclear power stations in course of construction for the Central Electricity Generating Board at Bradwell and Berkeley.

The Late André Coyne.

M. ANDRÉ COYNE who was well known as a designer of reinforced concrete dams of advanced design died in July at the age of sixty-nine. Some of his work, including the Kariba dam, has been illustrated and described in this journal in the course of the past fifteen years. M. Coyne is credited with designing over a hundred dams, many of them arched structures, which have been built not only in his native France but in other parts of Europe, Africa and Asia. He was associated with the Malpasset dam at Fréjus, which collapsed last year, but the report on the failure (see this journal for May 1960) exonerated the designer and builder. M. Coyne was trained at the Ecole Polytechnique (of France) and entered the Service des Ponts et Chaussées and, when a department concerned only with dams was inaugurated, he was transferred to the senior position in the Service Technique de Grand Barrages. He later became Inspector-General of the Service des Ponts et Chaussées, and gave up this position in 1945 when he entered private practice as a consulting engineer. He was decorated for his services in the French air force during the 1914–1918 War.

Prestressed Precast Construction of the New Dungeness Lighthouse.

THE new lighthouse (*Fig.* 1) on the English Channel coast at Dungeness is mainly of prestressed precast concrete construction. The structure, a preliminary description of which is given in this journal for January 1960, is 130 ft. high and has a cast-insitu base surmounted by the shaft of the tower which comprises sixteen precast rings each 5 ft. high and of 12 ft. diameter externally, the thickness of the walls of the rings being 6 in. At the top of the shaft, there are three precast rings in which there are several apertures for the fog-horn. This section is surmounted by two truncated-conical rings and a cap of 16 ft. diameter, above which is the light. Access to the top of the tower is by means of an internal helical stair.

Fig. 1.

Construction commenced in November 1959 and was completed within six months although interrupted by bad weather and high winds. The structure is designed to withstand the pressure of winds exceeding 80 miles per hour.

The Base.

The substructure, which is constructed of white concrete cast insitu, is founded in the shingle about 10 ft. below the level of the beach. Above ground it is in the form of a helical ramp embracing the machine room in which are the electrical controls, reserve generators, and fog-signal equipment. Panels of timber shuttering (*Fig.* 2) were used in the construction of the substructure.

Precast Rings.

A feature of the precast rings is that a quadrant of the helical concrete stair within the shaft is monolithic with each ring. Above each third quadrant there is a semi-circular landing. The mould for the sixteen main precast rings comprised concentric bands of steel plate stiffened with angles. The outer band was a complete circle and comprised two sections each 2 ft. 6 in. high and placed one above the other to form the outer mould for a 5-ft. ring. The inner band comprised four quadrantal sections each 5 ft. high and a key; one of the sections was arranged so that a quadrant of the stair could be attached to the ring. When each ring was cast bars projecting from the ring provided the reinforcement for the stair and landings.

When each mould was assembled, a spider of 12 ft. 8 in. diameter and having sixteen arms was fixed centrally in the mould (*Fig.* 3). The purpose of this fitment was to provide a working platform and the projecting arms formed a template for the ducts for the four vertical prestressing cables, which extend from the anchorage in the foundation to points near the top of the tower. The spider also located accurately the inner and outer bands of the mould. The edge of the platform provided the shutter for the upstand of the spigotted joint between successive rings.

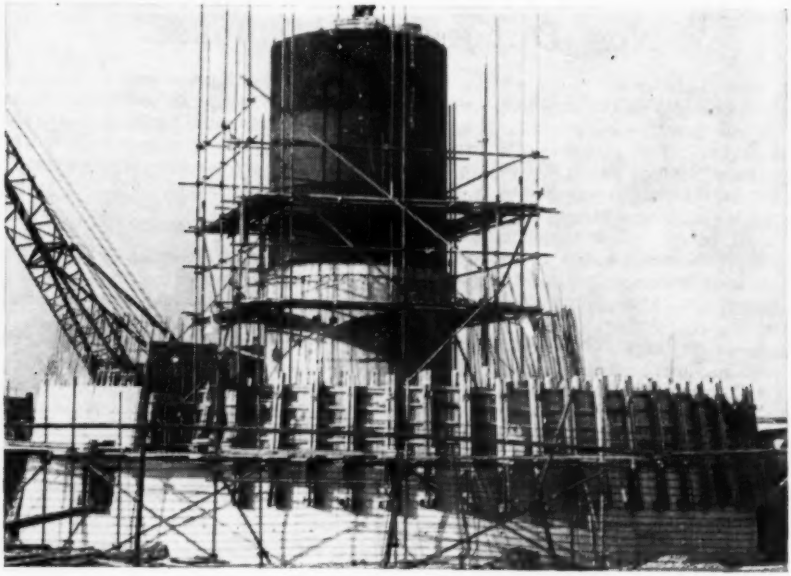


Fig. 2.

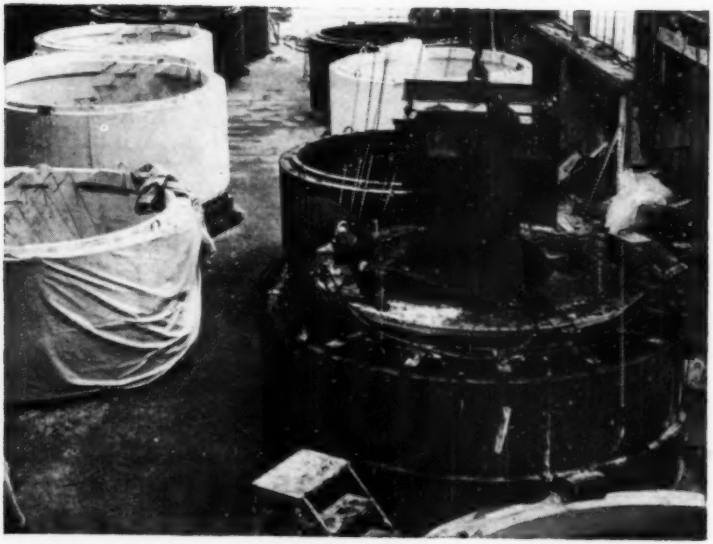


Fig. 3.

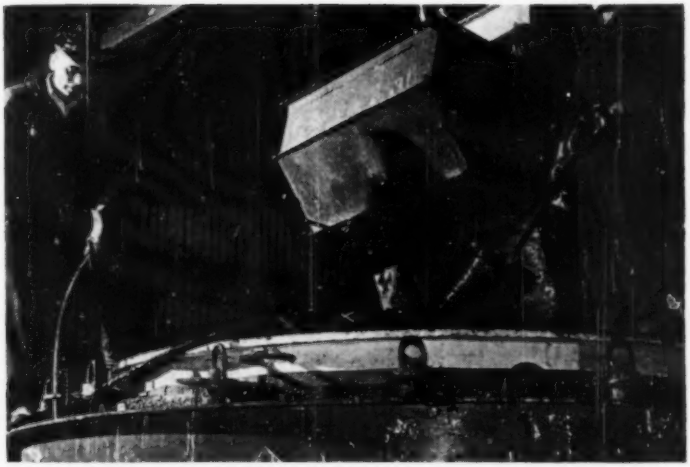


Fig. 4.

The sixteen main rings were cast in one mould which was set up in a factory (*Fig.* 3) fourteen miles from the site. The mould was filled with concrete which was deposited from skips on to the platform and shovelled into the mould (*Fig.* 4). Compaction was effected by means of internal vibrators. The moulds for the soffit of the stair and landings were separate from the main mould, but the stair and landings were cast within the rings before the rings left the factory. A ring with a quadrant of stair, and another with a quadrant of stair and a semi-circular landing are shown in *Figs.* 7 and 10 respectively. Upon completion of the casting the rings were encased in plastic sheeting and transported to the site on a low-loader trailer (*Fig.* 10).

The mould for the main rings was adapted for the three rings comprising the fog-horn section (*Fig.* 6) and for this purpose the mould was returned to the works where it had been made. The outer band was modified so as to provide for forming the apertures, but a new inner band was made in sixteen sections each of which corresponded to a pair of apertures. The

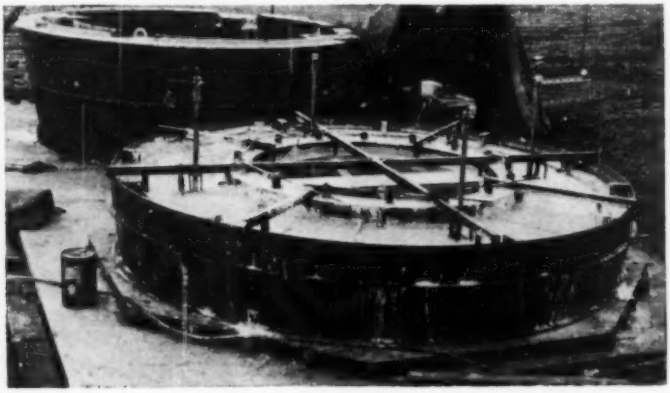


Fig. 5.

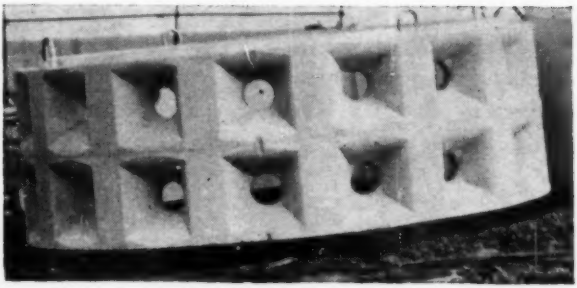


Fig. 6.

truncated-conical rings at the top of the tower were cast in steel moulds (*Fig.* 5) on the site.

The three rings in the fog-horn section, the two tapered rings and cap at the top of the tower, and six of the main rings are of white concrete. The remaining ten main rings are of black concrete, so that the alternate black and white banding (*Fig.* 1) is permanent.

Erection.

The precast rings were erected by means of a crane (*Figs.* 7 and 8) having a lifting

Fig. 7.

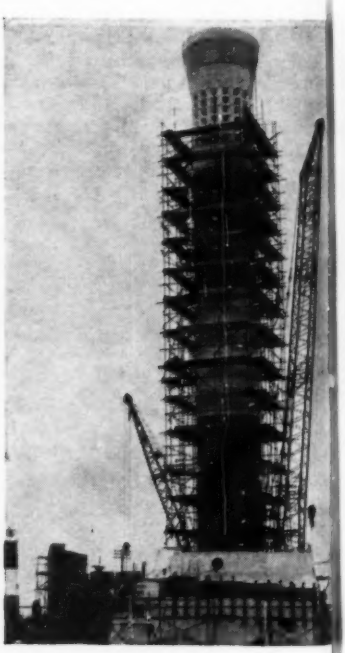


Fig. 8.

Fig. 9.

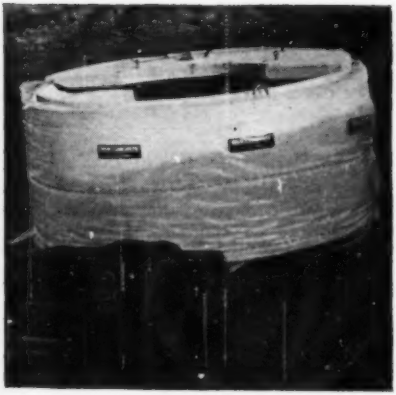


Fig. 10.

capacity of 11¼ tons and a jib 142 ft. long. The lifting tackle was attached to hoops embedded in, and projecting from, the wall of each ring. The bottom ring was located accurately by means of a steel ring fixed to the concrete of the substructure at the level of the ground floor. When all the rings were in position the four vertical cables were tensioned.

A view within the tower showing the stairs and landing is shown in *Fig.* 9.

The architects and consulting engineers are Messrs. Ronald Ward & Partners who collaborated with the engineers of Trinity House, the authority in charge of the lighthouses around the coast of Great Britain. The contractors were Taylor Woodrow Construction, Ltd. The most suitable proportions of the materials for the black and white concretes were investigated by Terresearch, Ltd. The prestressing system comprised Freyssinet mono-wire cables with anchors and jacks provided by Cable Covers, Ltd. Precast rings were made by Spun Concrete, Ltd., using steel moulds designed and supplied by Stelmo, Ltd., who also provided the moulds for the rings cast on the site.

Book Reviews.

"Reinforced Concrete Chimneys." By C. Percy Taylor and Leslie Turner. Second Edition revised by Leslie Turner. (London: Concrete Publications Ltd. 1960. Price 12*s*.; by post 12*s*. 9*d*. In Canada and U.S.A. 2.80 dollars.)

THE new edition of this book includes improved methods of the design of reinforced concrete chimneys especially as regards the resistance of annular sections subjected to bending and direct thrust for which some useful charts are given. A new chapter deals with the deflection and sway of tall chimneys due to the effects of wind and is a useful contribution to a subject on which there is very little literature. Design data also include methods of combining the stresses due to thermal changes with structural stresses; these methods are also applicable to the design of such structures as reinforced concrete tanks containing hot liquids and biological shields in connection with nuclear power stations. An example of a complete design of a chimney is given.

The construction of chimneys is not dealt with in detail except in so far as constructional procedure affects design. As in the previous edition, examples of early concrete chimneys are illustrated, but particulars of many recent, and some exceptionally tall, structures are given. Since the publication in 1940 of the first edition of this book, which is the only volume published in Great Britain dealing with concrete chimneys, one of the authors, Mr. C. P. Taylor, has died and the present edition has been revised by Mr. Leslie Turner.

"Practical Prestressed Concrete." By H. K. Preston. (London: McGraw-Hill Publishing Co., Ltd. 1960. Price 89*s*.)

THIS book describes in detail the application in America of the "Tentative Recommendations for Prestressed Concrete" published by the American Concrete Institute and American Society of Civil Engineers. The recommendations are given in full and numerical examples of the design of several types of structure are given with reference at each step to the appropriate clause of the Recommendations. Many of the methods of prestressing common in America are illustrated and described with examples of suitable applications. The properties of the various types of prestressing materials are also described and the "Criteria for Prestressed Concrete" published in America by the Bureau of Public Roads is given in an appendix.

For the American engineer this book is a useful introduction to prestressed concrete and provides a guide to the use of this method of construction for those who already have a knowledge of reinforced concrete design.

"Grundbau-Dynamik." By H. Lorenz. (Berlin: Springer-Verlag. 1960. Price 46.50 D.M.)

THIS book deals with the dynamics of soils as applied to the design of foundations of machines subjected to vibration and impact. The resulting settlement of the foundations and the resonance induced in the ground are considered for vibratory systems having concentrated masses, but vibratory systems having distributed masses, such as beams and rectangular frames, are also considered. Approximate methods and tables for determining natural frequencies, induced amplitudes and bending moments, assuming that vibrations are free and not damped, are given. Vibrations related to piles are not considered. A sound knowledge of German is required to enable some parts of the book to be understood.

Bulletins Received.

"Poisson's Ratio of Concrete used in Portuguese Dams determined from Strains measured Insitu." By M. Q. Guerreiro. (Lisbon: Laboratorio Nacional de Eugenhari Civil. Memória No. 135. 1958. In Portuguese with summary in English.)

"Thermal Behaviour of Concrete Dams." By A. Ferreira Da Silveira. (Lisbon: Laboratorio Nacional de Eugenhari Civil. Memória No. 125. 1958. In Portuguese with summary in English.)

"Rectangular Staircases without Beams." By J. Ferry Borges. (Lisbon: Laboratorio Nacional de Eugenhari Civil. Technical Paper No. 121. 1958. In English.)

"Design of Long Reinforced Concrete Columns." By B. Broms and I. M. Viest. (Bulletin No. 11. The Reinforced Concrete Research Council of the Engineering Foundation, U.S.A. 1958. Obtainable from the Portland Cement Association.)

The Design of Concrete Biological Shields for Nuclear Reactors.—II.*

By S. GILL, B.Sc. (Tech.), A.M.I.C.E., A.M.I.Mech.E.

Example (*continued*).

RESTRAINTS AT ROOF AND BOTTOM SHIELD.—The shape of the inner shield wall of the reactor in *Fig.* 2,† as simplified for the purpose of design, is shown in *Fig.* 4.

The temperature of the support of the bottom shield, which is monolithic with the 5-ft. wall, is 20 deg. F. lower than the temperature of the wall. The

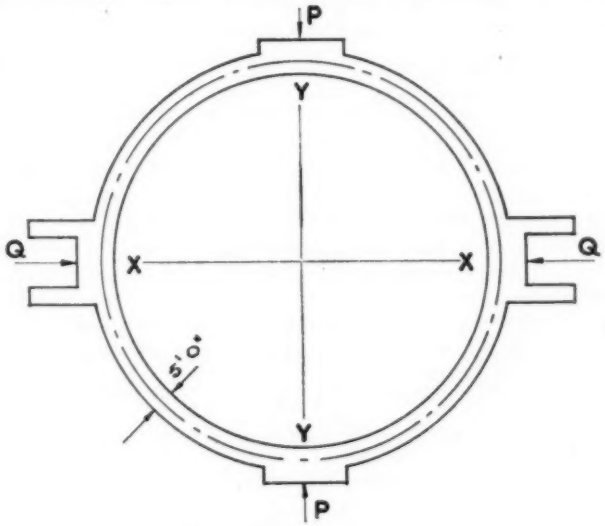


Fig. 4.

wall will therefore deflect, and the corresponding bending moments and shearing forces (which will be most severe if the wall is fully built-in at the base) can be calculated from expressions given by Prof. Timoshenko[2] for the deflection δ and rotation e of a long cylinder subjected to end actions Q_0 and M_0 per unit length, that is, if $B^4 = \frac{3(1-\sigma^2)}{R^2d^2}$ and $D = \frac{Ed^3}{12(1-\sigma^2)}$,

$$\delta = -\frac{1}{2B^3D}(BM_0 + Q_0) \quad . \quad . \quad . \quad . \quad (2)$$

$$e = \frac{1}{2B^2D}(2BM_0 + Q_0) \, . \quad . \quad . \quad . \quad . \quad (3)$$

in which R is the radius of the shield (inches), d is the thickness of the wall (inches), and σ is Poisson's ratio which is assumed to be zero. Assuming perfect

* Continued from August 1960. † See page 300 of August number.

restraint, $e = 0$. For a temperature difference of 20 deg. F. and $R = 500$ in., δ is $-0{\cdot}06$ in., giving values of 250,000 in.-lb. per inch for M_0 and -3800 lb. per inch for Q_0.

The average direct compressive stress at the bottom of the wall due to the dead load above is 180 lb. per square inch. The bending moment at any plane in the height of the wall is given by

$$M = M_0 \phi(B_x) + \frac{Q_0}{B} \zeta(B_x) \quad . \quad . \quad . \quad . \quad (4)$$

in which $\phi(B_x)$ and $\zeta(B_x)$ are functions of the distance down the cylinder; values of these functions are given by Prof. Timoshenko.[2] *Fig.* 5 gives the diagram of combined stress due to this moment and the dead load at various planes in the height of the wall. The maximum shearing stress occurs at the bottom and, if the effective depth is 57 in., is $\frac{3800}{0{\cdot}88 \times 57} = 75$ lb. per square inch.

The thickness of the roof varies around the circumference, and the walls also increase from 5 ft. to 9 ft. in thickness where the inner and outer shields combine. The restraint stresses due to differences of temperature between the roof and wall where the wall is 9 ft. thick cannot exceed those calculated for the position where the wall is 5 ft. thick. Accordingly, the worst condition is assumed to occur where the roof is locally 17 ft. 6 in. thick and bears on the 5-ft. wall. The fixed-end bending moment on the wall due to the roof occurs where a temperature gradient of 25 deg. F. through the wall has been assumed, and where the difference of temperature between the wall and the roof is 15 deg. F. The fixed-end bending moment of the 5-ft. wall (with $e = 0$) due to the difference of temperature of 15 deg. F. is $\frac{15}{20} \times 250{,}000 = 188{,}000$ in.-lb. per inch. The end bending moment due to the temperature gradient of 25 deg. F. through the wall is, from formula (1), $2{,}000{,}000 \times \frac{60^3}{12} \times 25 \times 0{\cdot}000006 \times \frac{1}{60}$ $= 90{,}000$ in.-lb. per inch. The total bending moment is therefore 278,000 in.-lb. per inch.

The fixed-end bending moment, calculated from formula (1), in the 17-ft. 6-in. roof for an equivalent gradient of 30 deg. F. is 1,320,000 in.-lb. per inch.

Since the roof and wall are connected, they act on each other, and the induced bending moments (acting in the opposite sense to the fixed-end bending moments) are calculated by considering the total moment to be distributed between the members according to their relative stiffnesses, which are obtained by comparing the reciprocals of the rotation of the members when subjected to a bending moment M per unit length of circumference with no deflection at the edge. For the 17-ft. 6-in. circular slab the rotation is $\frac{M}{E(-5{\cdot}5 \times 10^{-4})}$ radians, and for the 5-ft. cylindrical wall the rotation is $\frac{M}{E(-3{\cdot}57 \times 10^{-3})}$ radians. The relative stiffnesses are $\frac{\text{stiffness of 17-ft. 6-in. roof}}{\text{stiffness of 5-ft. wall}} = \frac{3{\cdot}57 \times 10^{-3}}{5{\cdot}5 \times 10^{-4}} = 6{\cdot}5$.

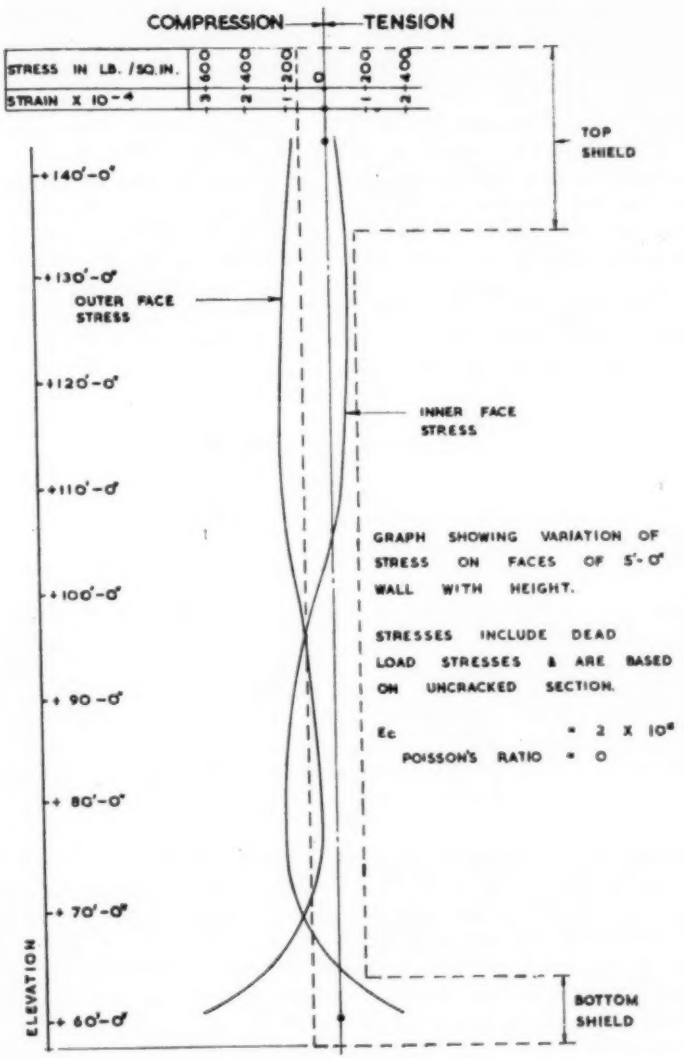


Fig. 5.

Therefore the final bending moment on the wall is $278{,}000 - \frac{1{,}598{,}000 \times 1}{6{\cdot}5 + 1}$ $= + 64{,}000$ in.-lb. per inch. Similarly, the final bending moment on the roof is $1{,}598{,}000 - \frac{1{,}598{,}000 \times 6{\cdot}5}{6{\cdot}5 + 1} = - 64{,}000$ in.-lb. per inch.

The shearing stress is obtained from the same principles. In the fixed-end

case, $e = 0$ and, from formula (3), $Q_0 = -2BM_0$. For the induced shearing force $\delta = 0$, and from formula (2) $Q_0 = -BM_0$. Hence the total shearing force at the top of the wall is $(188{,}000 \times 2B) - \frac{1{,}598{,}000 \times 1}{7{\cdot}5B} = 1240$ lb. per inch. The resulting shearing stress is only 25 lb. per square inch. The stress diagram in *Fig.* 5 illustrates the conditions at the top of the wall.

HORIZONTAL BENDING RESTRAINTS.—At a position near the equator, it is assumed that the effects of the restraints due to the roof and bottom shield are negligible, and that the difference of temperature between the 5-ft. inner wall and the double wing-walls shown in *Fig.* 4 is about 30 deg. F. The wing-walls on the X—X axis are assumed to offer perfect restraint to the wall, and the wall thickenings on the Y—Y axis are considered to offer partial restraint. Each thickening is regarded as a beam 24 ft. deep, 9 ft. wide and of 78 ft. span and is assumed to be fixed at the ends.

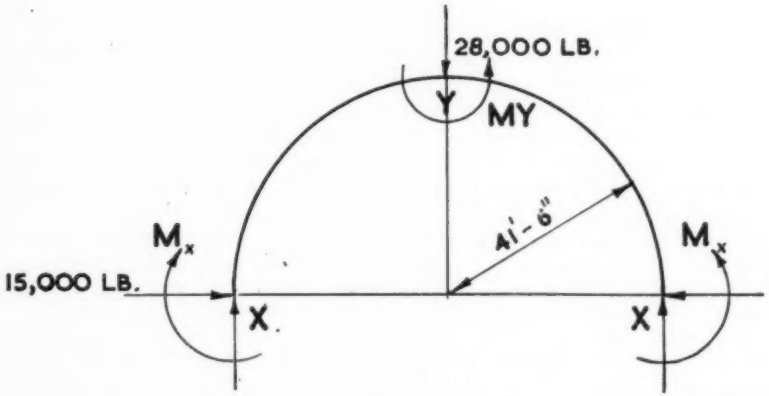


Fig. 6.

The structure is considered to be loaded first by forces Q in the X—X direction and then by forces P in the Y—Y direction. These forces and their resultant deflections are related in the formulæ given by Roark.[3] If perfect restraint by the wing-walls is assumed, there is no deflection in the X—X direction. The deflection in the Y—Y direction is that of the equivalent beam, and from the simultaneous equations that result, calculation shows that $P = 28{,}000$ lb. per foot, and $Q = 30{,}000$ lb. per foot.

To assess the distribution of bending moment, one half of the cylinder is considered as a fixed-end arch (*Fig.* 6), for which the restraint moments for no rotation are readily calculable.

The moments M_x and M_y are evaluated as $+2{,}220{,}000$ in.-lb. per foot (tension on inside) and $+1{,}720{,}000$ in.-lb. per foot (tension on inside) respectively. The resulting bending stresses are ± 308 lb. per square inch at X and ± 240 lb. per square inch at Y.

The circumferential stress due to a temperature gradient of 20 deg. F. across the cylinder walls has already been calculated to be ± 150 lb. per square inch.

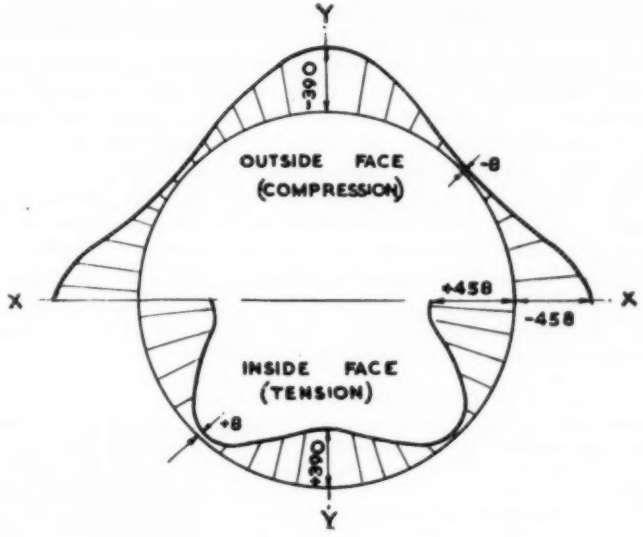


Fig. 7.

The total bending stress in the cylinder is therefore ± 458 lb. per square inch at X and ± 390 lb. per square inch at Y. The stresses at intermediate positions can be shown to be less; the distribution of stress is shown in *Fig. 7*.

If the fixed-end thickenings are finally considered to be loaded with a force of 28,000 lb. per foot as previously calculated, the maximum vertical bending moment is 170,000,000 in.-lb. and the bending stresses are ± 340 lb. per square inch. These stresses can be added directly to the temperature stresses to give the total vertical stresses at the outer and inner faces as ± 490 lb. per square inch at the equator.

The permissible tensile strain of 0·0005 corresponds to a concrete stress of 1000 lb. per square inch. Computations similar to those in the foregoing show that at no position in the structure does the total change of stress across a section exceed this value. The reinforcement provided serves therefore mainly as reinforcement against propagation of cracks.

Crack Control.

With a suitable cooling system, the internal thermal stresses can be minimized and cracking of the concrete reduced. The reinforcement is placed near the faces of the wall, where the tensile strength of the concrete is likely to be exceeded, and limits the cracks in width and ensures that where cracks occur they are fairly evenly distributed throughout the surface. This is important as it prevents the hazard caused by leaking of radiation through large cracks. Extensive cracking reduces the effective density of the shield, and it has been shown that a local reduction of density of 1 per cent. increases the local radiation by 10 per cent. To ensure even distribution of cracks, the reinforcement at a crack must be such

that when a crack reaches the greatest permissible depth an adjacent crack begins to form. It can be shown that compliance with the recommendations of the B.S. Code of Practice No. 114, which requires a total of 0·2 per cent. of steel near both faces of a load-bearing wall, gives a reasonable amount of reinforcement. In the example dealt with in the foregoing, the following reinforcement is provided vertically and horizontally near both faces of the shield walls: 4-ft. walls, $\frac{7}{8}$-in. bars at 12-in. centres; 5-ft. walls, 1-in. bars at 12-in. centres; 6-ft. walls, $1\frac{1}{8}$-in. bars at 12-in. centres; and 7-ft. walls, $1\frac{1}{4}$-in. bars at 12-in. centres. The 9-ft. walls are formed by the amalgamation of a 5-ft. wall and a 4-ft. wall, and in these positions the two complete sets of vertical and horizontal bars are provided where practicable. At some positions, however, from practical considerations, $1\frac{3}{8}$-in. bars at 12-in. centres only have been provided each way on the outside face. These quantities of reinforcement are at least as much as those recommended in the Code.

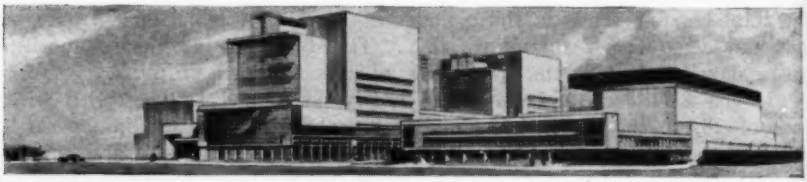
BIBLIOGRAPHICAL REFERENCES.

2.—TIMOSHENKO, S. and WOINOWSKY. S. "Theory of Plates and Shells." 1959. (See page 466 *et seq.*; a table of functions is given on pages 472 and 473.)

3.—ROARK, R. J. "Formulas for Stress and Strain." 1954. (See page 158 of third edition.)

[See also "Research on Biological Shields" on page 340.—ED.]

Nuclear Power Station at Dungeness.



THE contract for the construction of the 550-megawatt nuclear power station at Dungeness, Kent, has been awarded by the Central Electricity Generating Board to the Nuclear Power Group of companies which include Associated Electrical Industries, Ltd., John Thompson Nuclear Energy Co., Ltd., and the Nuclear Power Plant Co., Ltd. The value of the contract is about £50,000,000. (In general, the proportion of the total cost represented by the civil engineering and building works in connection with nuclear power stations is about a third.) The main civil engineering contractors are Sir Robert McAlpine & Co., Ltd.

The foundations of the structures will be of particular interest since the site is on a triangular headland of shingle which projects nearly five miles out to sea from a line of marshland. The shingle has been accumulating for the past fifteen centuries and its formation is generally considered to be due to the easterly drift in the English Channel which piles up at Dungeness vast amounts of flint and other stones, eroded from Selsey Bill, Chesil Bank, and elsewhere. The new lighthouse (see pages 341 to 345 of this number) at Dungeness is built on land which probably did not exist a century ago. The depth of the stratum of shingle is generally between 40 ft. and 50 ft. and this deposit overlies firm fine sand which extends to a depth of about 120 ft. below the general level of the ground. Below the sand are the deposits of hard clay known as the Hastings beds. The level of the ground water is about 10 ft. below the present level of the ground.

Work commenced on the site in August last, and it is expected that the station will be completed in 1965. An artist's impression of the station is shown in the accompanying illustration.

A Large Colliery Winder-tower.

THE reinforced concrete winder-tower (*Fig.* 1) recently completed at Wolstanton Colliery, near Stoke-on-Trent, is one of the largest in the country. The structure is 58 ft. square for the lower 119 ft., and about 58 ft. by 93 ft. above; the height is about 174 ft. (*Fig.* 2). The tower houses two sets of friction winding equipment, each set comprising a 3300-h.p. electric motor, a winding drum 16 ft. diameter, a deflector pulley, a 6600-volt generator, and auxiliary gear. A 40-ton electric overhead travelling crane, two 22-ton hand-operated gantry cranes, and four pairs of lifting beams form part of the permanent installation of the tower. All floors are served by a 30-cwt. lift and two steel stairs. The tower is symmetrically placed about the centre of the new downcast shaft, the inside diameter of which is 24 ft., and its depth will be finally 3900 ft. Each winder operates a four-deck cage and a 36-ton counterweight, both of which are suspended by four $1\frac{3}{4}$-in. locked-coil winding ropes.

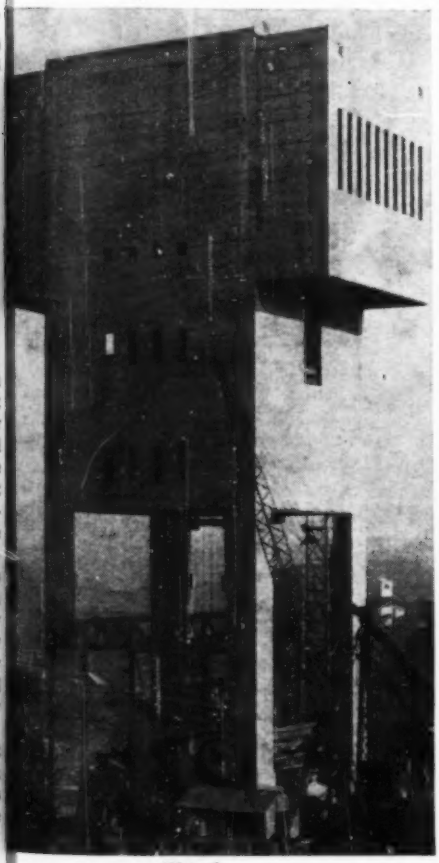


Fig. 1.

The external walls are of reinforced concrete of thicknesses varying from 9 in. to 24 in. Two pairs of the main beams carry the winding drums and the deflector pulleys. The upper beams are 14 ft. deep and the lower 13 ft. deep, and are connected by three pairs of vertical struts. They are supported on main wall beams, 29 ft. deep and 2 ft. wide, which in turn span between the main columns. The four main columns are L-shaped and 69 ft. high, the cross-sectional dimensions being 8 ft. by 8 ft. by 2 ft. The lift, stairs, and services are in the re-entrant corners of the columns. The rectangular openings between the columns will be closed when the shaft is complete.

Departure from the usual practice of placing both main motors on the same side of the centre line of the tower results in the centre of gravity of the loads being at the geometrical centre of the tower. The halves of the tower are nearly identical, and the total load is equally distributed on all four columns.

Two overhanging parts cantilever from the main stem of the tower. The hoisting hatches, which are 23 ft. long and 11 ft. wide, have removable steel covers.

The foundations are cylinders 65 ft. deep and having an outside diameter of 13 ft. and 18-in. walls. The cylinders are enlarged at the bottom to form bases of 20 ft. diameter. The caps and bases of the cylinders are heavily reinforced. Jacks are provided to correct tilting of the tower caused by differential subsidence.

The crane beams are monolithic with the walls and, together with the horizontal stiffening beams in the overhanging parts of the tower and the vertical ribs between the crane beams and the winder floor, increase the rigidity of the walls which support the roof. Except for these stiffening members, the walls are flush on both faces.

The shaft-sinking platform is 73 ft. above the ground, and supports a temporary steel grillage carrying the sheaves of the shaft-sinking gear. The platform is supported by the external walls and four reinforced concrete hangers suspended from the lower main beams.

Design.

The working stresses used in the design are in accordance with the British Standard Code No. 114 (1957). The total load on four columns during the winding is 7200 tons and the load suspended on each winding drum is 203 tons. The breaking load of eight ropes is 1200 tons, and this load is considered as an abnormal condition. Therefore the ordinary permissible working stresses are increased by 33⅓ per cent. in the hypothetical case of four ropes breaking, and by 60 per cent. in the unlikely event of eight ropes being loaded to their ultimate load. A wind pressure of 24 lb. per square foot of exposed area was assumed at all stages of construction.

All external walls are load-bearing and act as deep beams. The secondary beams of the floors span between the walls and the main internal beams. The two main wall-beams span 50 ft. and each supports a load of about 1700 tons. To assess the bending of the walls in the vicinity of beam seatings, it is assumed that the stiffness of a wall is equal to the stiffness of a column of the same depth as the thickness of the wall and of width equal to two-thirds of the distance between the floors.

The main internal beams at the lower level are designed to support their own weight, the weight of the motor-generator floor, the weight of the unset concrete in the upper beams, the constructional loading, and loads transferred by the hangers supporting the shaft-sinking platform. If the central struts connecting the lower and upper beams were constructed completely before removing the scaffolding from beneath the upper beams, the additional load would cause over-stressing of the lower beams. A simple measure was adopted to eliminate the uncertainties of the assumptions which would otherwise be necessary. A temporary gap was left at about mid-height of the central strut. Four 1½-in. bars were cast in the lower part of the strut and were free to move in sleeves in the upper part; the tops of the bars were threaded. After the scaf-

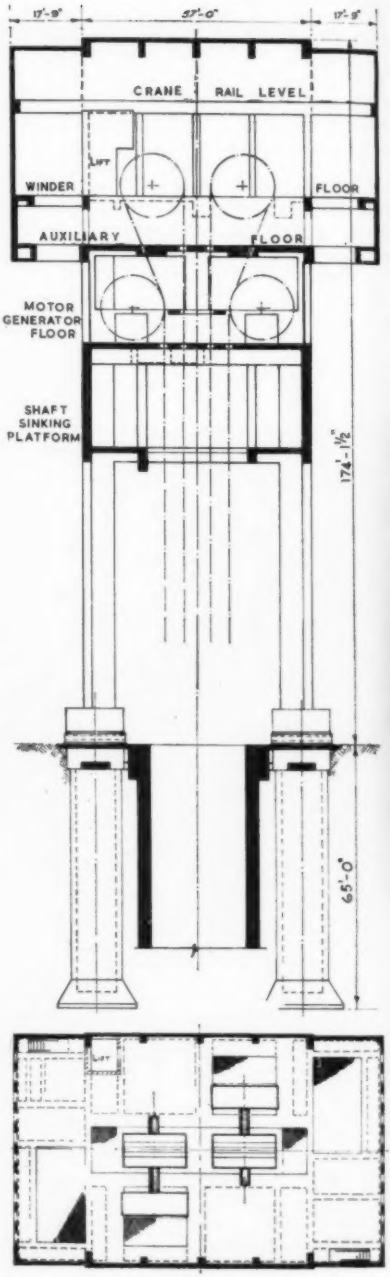


Fig. 2.

folding supporting the upper beams had been removed, the gap was filled with well-rammed concrete and, a month later, the bars were tensioned by tightening nuts on the threaded ends. Justification of these measures is based on the following:—(a) The ratio of span to depth of each beam is about four, and even small deflections would result in a considerable increase of stress. (b) Both pairs of beams were cast during the winter. (c) A small factor of safety is adopted for rope-breaking conditions; such loads would be instantaneous and would not allow the redistribution of stresses likely in the case of loads gradually applied.

The method of construction adopted simplified the design of the main beams. Each beam supports the dead load independently of other beams. The sum of the design loads on the upper and lower beams is equal to the total load on both beams. The design load on each beam is approximately equal to the load the beam would support if the total load were shared by each beam proportionally to its stiffness. The central strut is 6 ft. wide. Its additional purpose is to resist a horizontal shearing force of 114 tons which occurs if the ropes break. This horizontal force would be applied at the centre of the winding drum and an equal force in the opposite direction would act at the centre of the deflector pulley. These forces could not be transferred to the external walls through the floor slabs because of the presence of large openings, some of which extend from the main beams to the external walls.

The main columns are designed for normal working loads, wind pressure, and an instantaneous vertical movement of 1 in. of any two columns not diagonally placed. The design also took into account intermediate stages of construction, such as occurred when the tower was only partly completed but had to withstand the horizontal forces caused by wind and by shaft-sinking operations.

The tower is on an embankment about 80 ft. above the original valley. The foundation cylinders are founded on a variegated red marl, the permissible bearing pressure on which is 7 tons per square foot. The tops of the cylinders, which are seen in *Fig.* 3, are connected

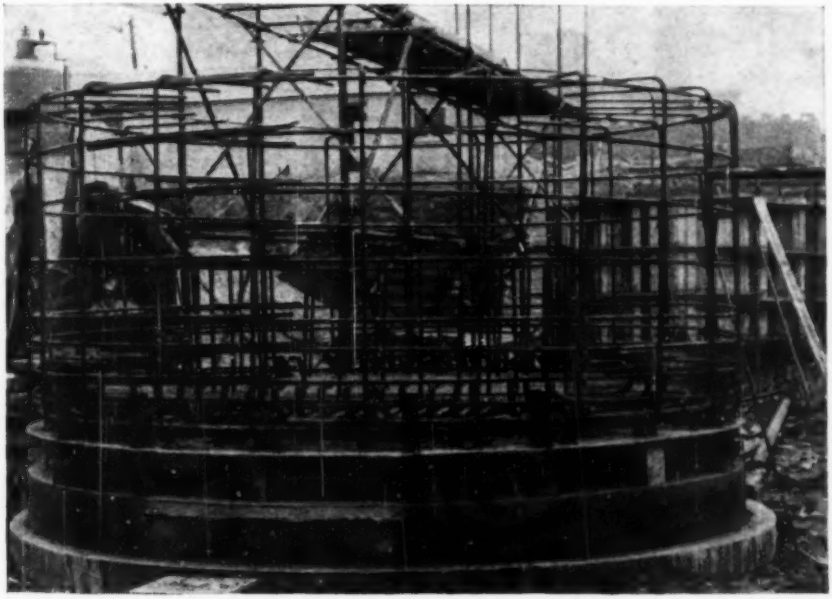


Fig. 3.

by ties 6 ft. wide and 21 in. deep. It is assumed that the flexibility of these beams in a vertical direction prevented transference of large loads supported by them on to the cylinders.

The Jacks.

Jacks are incorporated in the foundations to counteract movement due to subsidence. Vertical movement may be represented by two rotations about horizontal axes intersecting at 90 deg., and a translational movement. The four columns form a basic rectangle, two adjacent sides of which are considered to be the axes of rotation. By simultaneous jacking up of two adjacent columns, one component of the rotation is removed. Repeating the operation on the two columns opposite the other axis of rotation, the tower is brought back to a vertical position.

Six jacks are provided under each column (*Fig.* 4) and are operated by one pump, a reflux valve being provided to counteract possible failure of the jacking system. The degree of jacking will be measured by Mercer gauges. The column bases are circular in plan and have a central key projecting into a recess in the top of the cylinders. There are six sliding wedges at each column, which are spaced equally in the annular space around the central key. Each wedge is sandwiched between two steel plates (*Fig.* 5) which were kept at the correct distance during construction by means of spacer bolts. The bolts will be cut through before the first jacking operation. The jacking will be achieved by Freyssinet flat-jacks placed alternately with the wedges around the periphery of each base. The wedges will be driven home during jacking. For jacking above the greatest vertical travel of the wedges, steel shims will be provided.

The wedges supporting the bases are located on a pitch-circle of 11 ft. 6 in. diameter, and consequently the columns could not be designed as if hinged at the bottom. Jacking up of two columns will cause bending of the other two. It was estimated that the cost of articulation of the columns at the level of the jacks would be prohibitive, and therefore the columns are strengthened by increasing the amount of reinforcement. The bending stresses caused by jacking could, if necessary, be relieved by inflating the jacks just sufficiently to take the load off the wedges and re-adjusting their position. The force applied by the jacks is concentric and causes no bending of columns. Re-driving the wedges under such conditions eliminates " locked-in " bending stresses.

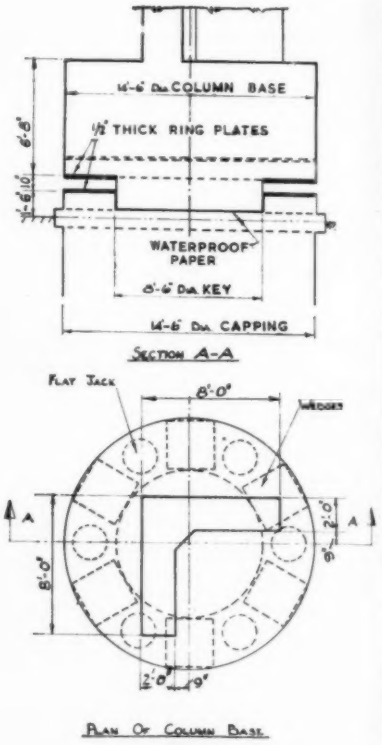


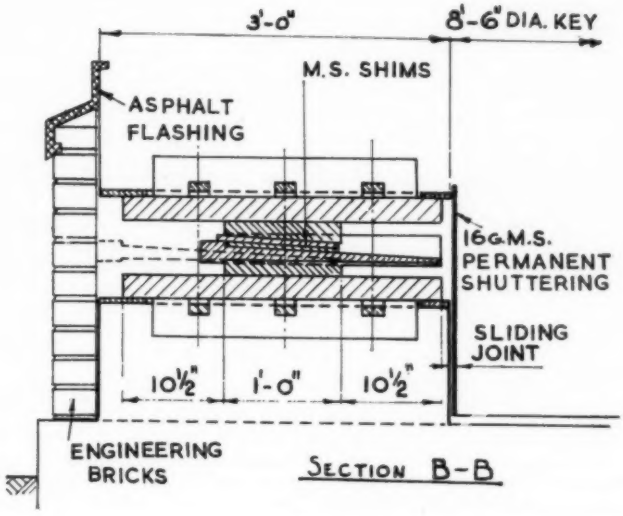
Fig. 4.

It is believed that the total weight of the tower, about 7000 tons, is the greatest for which jacking has yet been provided.

Construction.

The foundations were constructed within four months. Drain pipes of 2 in. diameter were built into the bases as a safeguard against accumulation of ground water and arranged to discharge into the shaft. As a precaution against sulphate attack and ingress of water, the cylinder walls were pressure-grouted after construction using sulphate-resistant cement.

For the superstructure the Contractor had to provide a concrete having a crushing strength of 4000 lb. per square



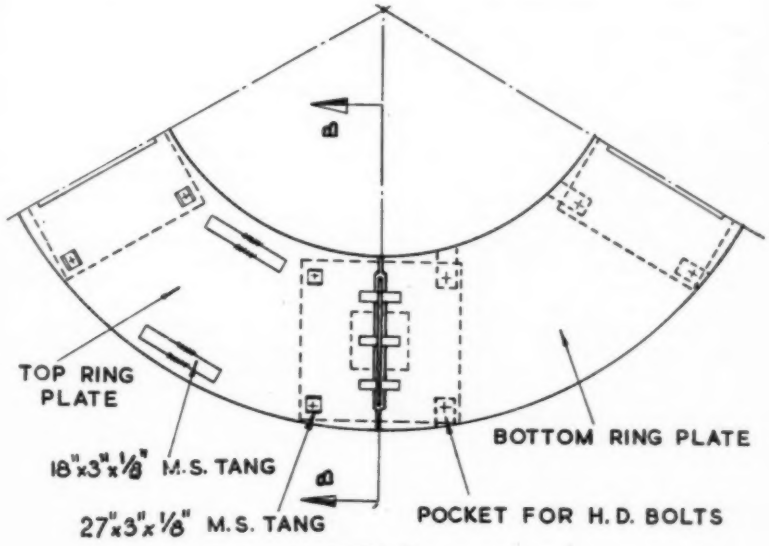


Fig. 5.

inch at twenty-eight days. The mixture adopted was 743 lb. of gravel, 392 lb. of sand, 210 lb. of cement, and an average of 6¾ gallons of water, after due allowance had been made for the water content within the aggregates. Zone No. 1 sand from local sources was used. Six cubes were made daily and the strengths attained were 4000 to 4700 lb. per square inch at seven days and 6800 to 7200 lb. per square inch at twenty-eight days.

The concreting plant included a silo for loose cement, and an electrically-operated scoop for feeding the aggregates

into a 14/10 mixer with a weigh-batcher. This arrangement permitted the concrete-mixing operations to be carried out by two men. The concrete was transported in rubber-tyred skips which were carried up the structure on a 30-cwt. hoist. Compaction of the concrete was by means of 2½-in. diameter electric internal vibrators, the standard frequency of which was 12,000 r.p.m. but was increased to 13,000 r.p.m. as this speed was found to produce better results. Concreting was carried on throughout wintry conditions, the precautions taken being steam-heating of the aggregates, the addition of 2 per cent. of calcium chloride to ordinary Portland cement, and commencing concrete operations when the outside temperatures attained 28 deg. F. and ceasing at about 3 p.m., which ensured initial set to take place before detrimental action by frost was likely to occur.

The scaffolding operations were complicated as openings were required to afford access to the shaft-sinking operations, and temporary structural steel bridges were necessary to span such openings. A complication arose since sinking the shaft was held up until the deflector-pulley beams were cast, and these beams had to be supported from the ground during the curing period, as it was feared that, if propped from the structure, resulting deflections in the structure would be inherent in the pulley beams. The beams are 95 ft. above the ground and were supported during casting operations by scaffolding supported on a grillage formed of six 24-in. by 7½-in. steel beams spanning 50 ft. over the open shaft and founded on the shaft-collar. The deflection of the grillage was ½ in.

Steel shutters were used throughout, purpose-made steel forms being used for the internal faces of the columns. The shutters, which were lifted by block-and-tackle, were set accurately and as a result at no point in the structure does the displacement from the vertical exceed ¼ in. The columns were constructed in lifts of 6 ft. each. It was found difficult to handle 1½-in. bars 40 ft. long, and subsequently 20-ft. bars were supplied, the ease of erection and handling offsetting the cost of the extra quantity of steel. When concreting reached a height of 73 ft. there was a discrepancy of ¾ in. from the designed level, and this was attributed to accumulative shrinkage.

A plasticiser was used in the concrete for the beams because of the difficulty otherwise of placing the concrete around the congested reinforcement. The deflector-pulley beams which are 13 ft. deep, deflected about ¼ in., which was considerably less than the camber provided on the shuttering. As it was necessary to expedite stripping of the supports of these beams to enable shaft-sinking operations to proceed, the beams were cast first to a depth of 4 ft. 10 in. which, upon hardening, formed a self-supporting section capable of carrying the load imposed when the remainder of the beam was cast. Three further lifts were added to complete each deflector-pulley beam.

The walls were cast in 5-ft. lifts, a timber fillet being provided at construction joints.

The floors are finished with 1½-in. granolithic which was laid after the plant was installed. The roof is insulated with a vermiculite screed which is covered with a cement-sand screed laid to falls and sealed with a layer of rock asphalt. Steel rings are built into the roof for the attachment of safety harness for maintenance workers.

The tower was constructed for the National Coal Board, whose permission to reproduce the illustrations in *Figs.* 1 and 3 is acknowledged. The consulting engineers are Messrs. C. H. Dobbie & Partners. The contractors for the foundations were Cementation, Ltd., and for the superstructure Messrs. Sir Alfred McAlpine & Sons, Ltd. We are indebted to Mr. W. J. Bygott, A.M.I.C.E., Divisional Engineer, West Midlands Division of the National Coal Board, and Mr. D. Robak, Dip. Ing., of Messrs. C. H. Dobbie & Partners, for the information on which this article is based.

Prestressing Companies Abroad.

CABLE Covers, Ltd., announce the formation of a subsidiary company called Ancarite Incorporated of New Jersey, U.S.A., and a joint company called C.C.L. (Australia) Pty., Ltd. of Sydney, Australia. These companies have been formed with the object of increasing the use of British prestressing systems in these two countries.

FIFTY YEARS AGO.

From "CONCRETE AND CONSTRUCTIONAL ENGINEERING", September, 1910.

A Long Reinforced Concrete Railway Viaduct.

"One of the largest reinforced concrete viaducts in the world has recently been completed at Rotterdam. The length of the viaduct is about 5450 ft. The superstructure of the city section, exclusive of the terminus and yard, comprises sixty-three normal spans, with fifty-eight piers and six street crossings, with one small and twelve large piers. The single span crossings vary in length from 33 ft. to 71 ft. The longest crossing, 88·6 ft., has a middle pier. The piers which support the normal spans are 25·6 in. thick, and the distance between these piers is from 26 ft. to 28 ft.; the thickness of the bridge piers varies from 8·2 ft. to 17·5 ft., according to the length of the crossing. Each of the piers of the normal spans is composed of four rectangular columns 18 ft. high, 15·7 in. wide, and 25·6 in. thick, connected by two walls, 3 in. thick, and by a common base of reinforced concrete, which distributes the weight over the plain concrete foundation. These columns support an arched girder 12 in. wide, 57 in. deep at the ends, and 18 in. deep in the middle. Each girder lies vertically under a rail of the double track. The concave lower surfaces of the four girders of the span are connected together by a sheet of reinforced concrete, 3 in. thick, which is jointed to the walls which flank the columns. The flat upper surfaces of the girders are connected by a concrete floor, of an average thickness of 5 in., which supports the ballast and track. The section outside the city is 3150 ft. long, and includes six street crossings and three aqueduct crossings, in addition to seventy-nine normal spans; except at street crossings, the structure rests directly on piles."

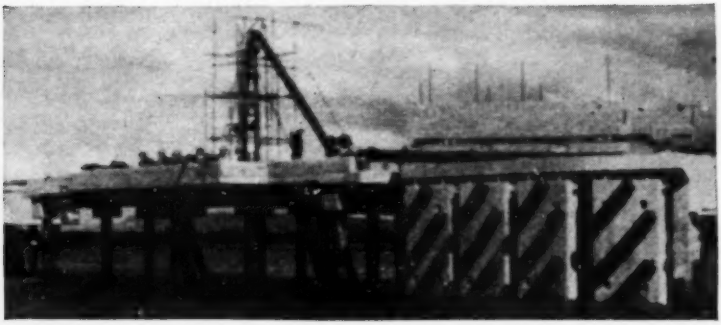
American Building Codes.

THE supplement for 1960 to the "1958 Compilation of A.S.T.M. Standards in Building Codes" was published recently (price 3.25 dollars from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., U.S.A.). The supplement contains particulars of revised standards and new and revised tentative standards. One hundred documents have been revised and there are thirteen new standards. The subjects dealt with include admixtures, aggregates, asbestos-cement products, bituminous roofing and waterproofing, bricks, cement, structural clay-tiles, concrete, concrete pipes and blocks, gypsum, iron, lime mortar, building stones, drain tiles, plastics, refractories, and wooden and steel products. Fire tests, flash-point tests, and general methods of testing are included.

A Memorial to Mr. A. E. Wynn.

A MEMORIAL to the late Mr. A. E. Wynn, the concrete engineer and author of books on concrete engineering, who died in 1956, has been established in the library of the new building of the Portland Cement Institute, formerly the Cement and Concrete Association of South Africa, at Johannesburg. The memorial is known as the "Wynn Collection" and takes the form of a case containing Mr. Wynn's books and articles and will include other books which will be purchased with money donated by his widow, who performed the unveiling ceremony.

Rubber Fenders on Dolphins.



THE accompanying illustration shows the arrangement of rubber fenders on the east mooring dolphin of the jetty built recently to accommodate tankers up to 18,000 tons supplying oil to the Coolkeeragh Power Station now in course of construction on the southern shore of Loch Foyle, near Londonderry, for the Electricity Board for Northern Ireland. There are 300 feet of hollow cylindrical rubber fenders in lengths from 3 ft. 6 in. to 7 ft. 9 in. The external diameter of the fenders is 15 in. and the internal diameter 7 ft. 9 in. The fenders were supplied by the Goodyear Tyre & Rubber Co. (Great Britain), Ltd.

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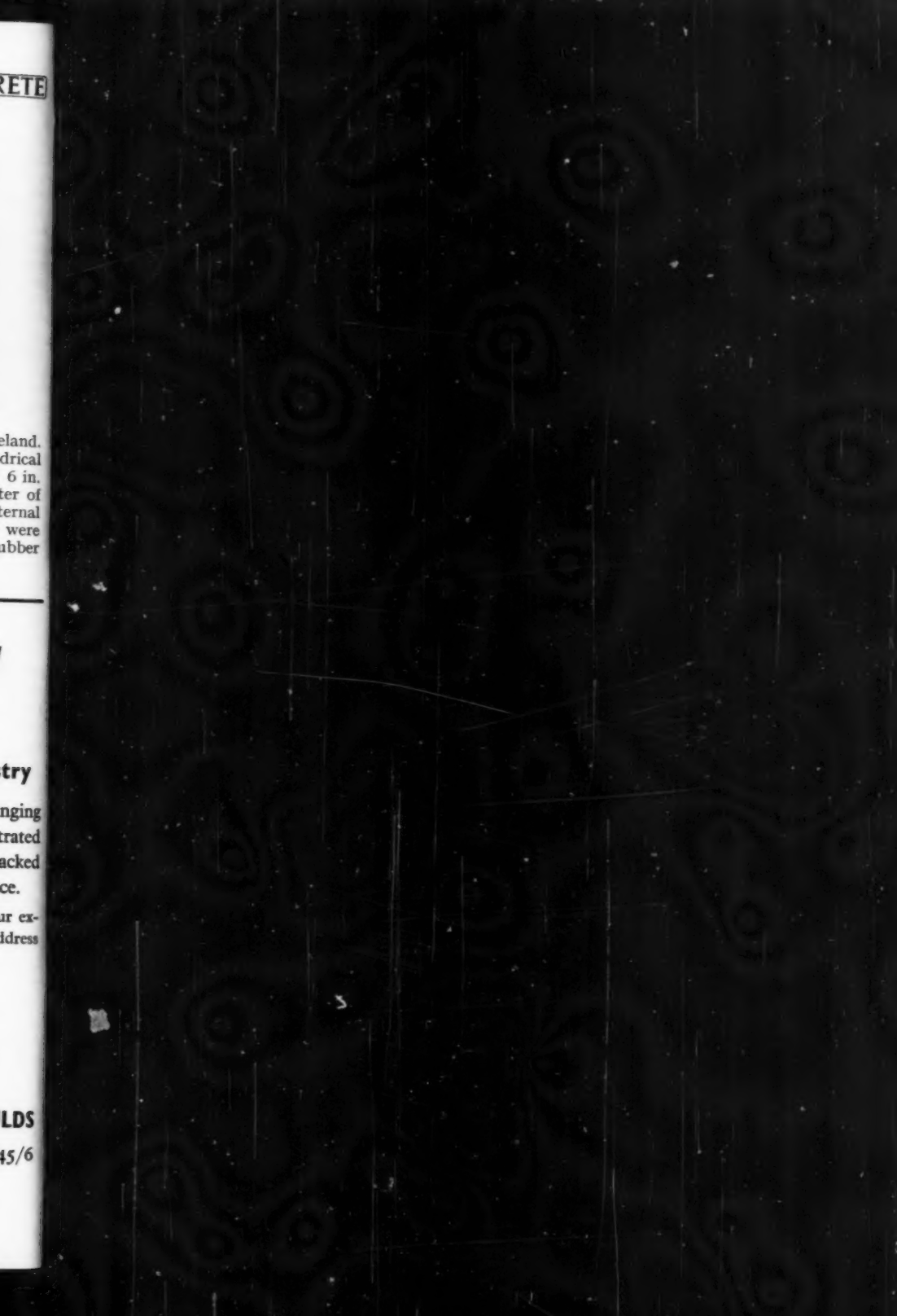

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SITUATIONS VACANT. Structural engineers required in Architect's Department, L.C.C. (salary up to £1250), in (*a*) *Structural Engineering Division*—Extensive programme includes multi-storey flats, schools, offices, warehouses, and other buildings. (*b*) *Structural Engineering Division*—To deal with applications in respect of special structures under Part IV of the London Building Act (A) Act, 1939, and the constructional by-laws. Interesting work involving consideration of unconventional forms of construction. (*c*) *District Surveyors' Service*—Work mainly outside involving negotiations with architects, engineers and surveyors, and supervision of works in progress. Good prospects in all these aspects of the Council's work. Form and particulars from HUBERT BENNETT, F.R.I.B.A., Architect of Council (EK/CCE/1638/9), County Hall, London, S.E.1.

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SITUATIONS VACANT. CLARKE, NICHOLLS & MARCEL require for their new Bristol offices designers, detailers and draughtsmen, experienced in reinforced concrete. Excellent opportunities in an expanding organisation. Positions are pensionable, and offer first-class experience for those studying for professional qualifications. Apply, in writing, to 10 Apsley Road, Clifton, Bristol, 8.

SITUATIONS VACANT. Reinforced concrete designers and draughtsmen with knowledge of building construction required by precast concrete specialists at their Head Office near Guildford. Varied work with good prospects, superannuation, etc. Salary by arrangement according to qualifications and experience. Apply to THE SENIOR STRUCTURAL ENGINEER, MARLEY CONCRETE LTD., Peasmarsh, Guildford, Surrey.

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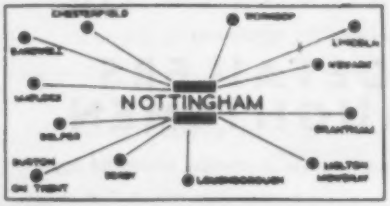

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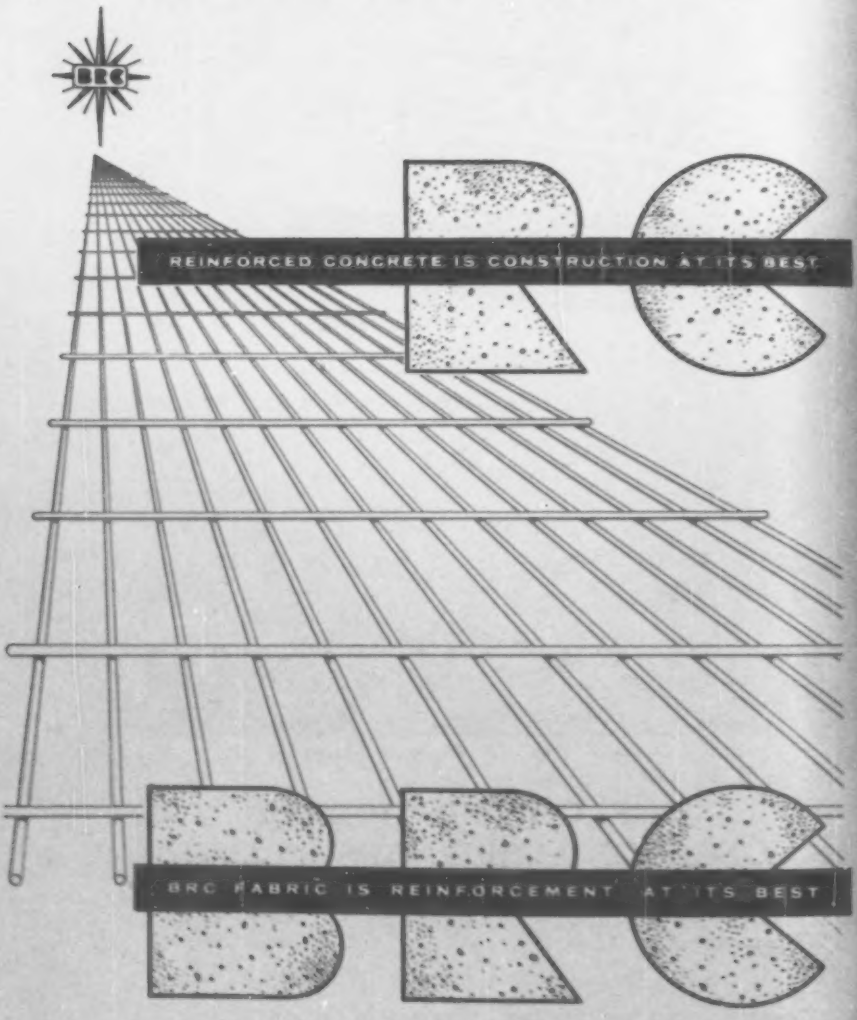

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